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# Development of Habitat Assessment Criteria for Freshwater Mussels, for use in Environmental Modeling of Effects of Commercial Navigation Traffic

by


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Summary

An attempt was made to develop habitat suitability models for use in assessing effects of future commercial navigation traffic on mussels inhabiting gravel-bars in large rivers. Literature review and consultation with mussel biologists indicated that habitat suitability for freshwater mussels could best be measured in terms of substrate stability, near-substrate turbulence and sediment deposition. This effort focused on effects of substrate disturbance, specifically as may result from the hydrodynamic forces caused by moving tows. To evaluate effects of substrate disturbance on mussels, biologists with expertise in mussel ecology were asked to estimate the depths into the substrate that different size-classes and species of mussels typically burrow in gravel-bar habitat. Biologists were also asked to estimate mortality rates for mussels dislodged from the substrate. Although over 20 biologists initially agreed to participate, fewer than 10 were able or willing to estimate substrate-depths typically occupied by mussels, with only two attempts to describe burrowing differences among species and three estimates specifically for juvenile mussels. Only two respondents were willing to estimate mortality rates. Five additional mussel experts reviewed a summary of these responses and generally reiterated the probable variability in both mussel depths in the substrate and mortality rates (depending on local conditions), the importance of considering disturbance frequency, and the need for field studies to provide relevant data.

It was concluded that only very general habitat suitability models could be constructed without supporting field data. Two general models were recommended, one for juvenile mussels (up to about three years of age) and one for older mussels. For both age groups, an index of habitat suitability was associated with depth of substrate disturbance and frequency of disturbance. These basic models were constructed to provide a starting point for considering effects of navigation traffic.

## Introduction

This report summarizes efforts made to develop habitat suitability criteria for use by the Louisville District, U.S. Army Corps of Engineers to evaluate potential effects of future commercial navigation traffic on freshwater mussel beds. The ACOE has developed a habitat-based method, the Navigation Predictive Analysis Technique (NAVPAT), which simulates and assesses biological impacts of pulsation-type alterations caused by passage of large commercial vessels. The NAVPAT model presently employs habitat suitability models for 15 species or life-stages of fishes to evaluate effects of physical habitat modification (e.g., substrate disturbance, velocity pulses) associated with commercial traffic activities. These models do not presently address effects on freshwater mussels (Bivalvia, Unionidae) inhabiting navigable rivers. Freshwater mussels are ecologically and economically important in North American rivers. Therefore, we have attempted to assemble available data and expert opinion to develop a model for inclusion in NAVPAT to evaluate potential effects of future commercial traffic on freshwater mussel beds, focusing on coarse, stable substrate areas.

Development of habitat suitability indices entails identifying the physical habitat variables that both influence habitat value for the target organisms and are potentially affected by management actions, and then estimating the effects of changes in those variables on habitat suitability. Habitat suitability indices frequently are developed from field quantification of habitat use by target organisms, or from published data describing relative abundances of target organisms in various habitat conditions. In the absence of resources to support on-site research, or published field data, biologists have used a consensus of expert opinion to estimate habitat suitability relationships for organisms of special interest. Clearly, empirical data provide the best basis for modeling effects of habitat alteration on populations (although problems associated with non-transferability of habitat relationships developed at other localities, and with observations made in already degraded habitats, may limit the usefulness of field data). In the case of freshwater mussels, habitat suitability models are not available, although the extensive literature on species distributions and biology includes observations of physical habitat conditions associated with many mussel species. Additionally, a subset of federal, state and private aquatic biologists together represent a pool of informed opinion potentially useful for estimating habitat suitability relationships for mussels. Thus, we initially searched for published data indicative of habitat requirements of mussels in relation to the hydrodynamic forces generated by moving tows, and then asked biologists with expertise in mussel ecology to help develop habitat criteria.

Procedures

1. Identification of relevant habitat variables.

Examination of published data (see Attachment A) strongly indicated that describing habitat in terms of water depth, current velocity or substrate size would not adequately characterize suitability for most mussels typically inhabiting coarse, stable gravel bar habitat. Many or most lotic mussel species appear capable of inhabiting wide ranges of depth, current velocity and substrate. However, published studies do provide evidence that substrate stability, rate of silt deposition, and near-substrate turbulence all affect habitat suitability for lotic mussels.

Two meetings were held to explore habitat criteria development. In an initial meeting (3 November 1993, USFWS office, Cookeville TN) FWS, ACOE and NBS biologists discussed the feasibility of modeling substrate displacement resulting from tow passage, and ways to incorporate frequency of substrate disturbance into a measure of habitat suitability. We also discussed modeling sediment build-up on mussel beds and possible effects of non-lethal, near-substrate turbulence on, e.g., reproductive activities, juveniles and habitat suitability for host fishes. We generally agreed that these variables held promise for quantifying potential effects of tow passage on habitat suitability for mussels, and discussed whether it would be better to develop a model applicable to mussel assemblages, or to target a species for which habitat, host fish, and other life history data were available. We decided to hold a meeting with a few biologists having expertise in freshwater mussel ecology who could (1) help to evaluate the usefulness of our proposed habitat variables, (2) identify candidate species for model development, (3) draft a list of mussel experts possibly willing to participate in model development, and (4) develop draft habitat suitability models for submission to experts.

The second meeting (11 January 1994, USFWS office, Cookeville TN) was partially successful in meeting our goals. FWS, ACOE and NBS personnel met with three biologists representing diverse experiences in mussel research, and generally agreed on the following:

- Long-term substrate stability is a primary response variable for evaluating effects of alternative barge traffic scenarios on gravel-bar mussel beds. Additional siltation on existing gravel-bar mussel beds should not occur as long a river flow patterns are not altered.
- Juvenile mussels, because of their relatively low specific gravity, are more vulnerable to displacement than adults unless juveniles deeply bury soon after dropping off the host fish. Juveniles may be present throughout the year because of variable reproductive periods within an assemblage, and slow growth. A conservative approach would be to assume mussels have juveniles present, and are metabolically active, year-round.
- Habitat suitability, relative to effects of tow traffic, depends both on the depth and frequency of substrate disturbance. Disturbance should be defined differently for small and large mussels. For mussels smaller than about 10 mm in length, disturbance might be defined by the movement of sand or silt (caused by velocity surges), whereas for larger mussels, movement of gravel or larger particles might constitute a disturbance.

We discussed a modeling approach that would address effects on substrate stability by estimating the velocity (V1) at which small particles on a gravel-bar begin to leave the substrate, and the higher velocity (V2) at which all the fine particles in the top few cm of the substrate would be washed into suspension. Then, we would ask experts to estimate the reductions in habitat suitability for small mussels associated with V1 and V2. Similarly, hydraulic models could estimate velocities at which gravel starts to move (V1), and at which gravel is disturbed to some depth into the substrate (V2), and ask experts to estimate the associated reductions in habitat suitability for large mussels. The effects of an individual event (tow passage) could then be estimated in relation to the resulting velocity surge and depth of substrate disturbance. We discussed the need to incorporate a measure of disturbance frequency in estimating habitat suitability, but we did not arrive at a method for doing so. We also did not develop draft suitability curves in relation to velocity surges. Finally, the group recommended against trying to develop species-specific models, suggesting instead that we include a list of mussels occurring in Ohio River gravel-bars, to which a general habitat suitability model would be applied.

2. Survey of experts.

An initial questionnaire was developed that addressed impacts of disturbing the sand and gravel matrix containing a mussel bed to various substrate depths and with increasing frequency. The questionnaire asked respondents to sketch x-y plots to describe the reduction in habitat suitability (y) of disturbing sand-sized (for small mussels) or gravel-sized (for large mussels) particles to increasing depths (x) in the substrate. Respondents would also be asked to estimate effects of increasing the frequency of events of various magnitudes (i.e., that decreased habitat suitability from a base value of 1.0 to 0.7 for a "small disturbance", to 0.5 for a "moderate disturbance", and to 0.2 for a "strong disturbance") on overall habitat suitability for small and large mussels at a given location. This approach would have required respondents to translate substrate disturbance into reduction in habitat suitability, based on their opinions or knowledge of how vulnerable small and large mussels are to displacement (i.e., how deeply most individuals bury) and how quickly individuals or populations can recover from being dislodged or displaced (i.e., by reburying or, in the case of populations, by recruiting replacement juveniles). After discussion and input from FWS personnel, we abandoned this questionnaire in favor of a more direct approach.

The revised questionnaire (Attachment B) asked respondents to estimate how deeply into the substrate gravel-bar mussels typically bury, and to describe differences among species and size-classes in their vertical depth distributions. Respondents were also asked to estimate the probability that an individual mussel would not survive being dislodged from the substrate, and to specify size- and species-related differences in mortality rates, as possible. This information, i.e., the vertical profile of mussels within gravel-bars and mortality rates of dislodged mussels, could be used to estimate the reduction in habitat suitability when a velocity surge created by a passing tow disturbed the bottom substrate to a given depth. The cumulative effect of repeated passing tows over a specific location on a mussel bed could be estimated by summing successive reductions in habitat suitability (estimated from the proportion of a population disturbed in each event, multiplied by the estimated mortality rate) at that point through time.

The revised questionnaire was mailed to 21 biologists (Attachment C) who verbally agreed to participate. Eleven individuals responded, and eight answered one or more of the questions. Tables 1-3 summarize responses. All biologists responding to the questionnaire, and several who declined to respond, stressed the lack of data available concerning either vertical distributions or mortality rates, and most emphasized the need for field research on these basic questions. The eight individuals who did respond agreed on the following:

(1) Size-classes of mussels differ in their vertical distributions within a gravel-bar. Further, 5 of 7 respondents expected vertical distribution differences among species. However, only three biologists offered estimates of vertical distributions for small versus large mussels or for different groups of species (Table 1). Estimates of the total depth above which 99% of a mussel assemblage should occur ranged from 12 to 36 cm, with a mode of 15 cm. Two reviewers explicitly noted the controlling influence of substrate compaction on the depth to which mussels bury; mussels are likely to be more shallowly buried in more firmly compacted gravel bars, but may be deeper in looser gravel with sufficient interstitial flow.

(2) Mortality rates following mussel dislodgement probably differ both among size-classes and among species (Table 2). Only 2 respondents offered estimates of mortality rates.

(3) Mussel species differ in their susceptibility to dislodgement, in part because of morphological differences (Table 3). Respondents differed in opinion as to whether differences should or could be incorporated into impact assessments.

Other concerns were raised by several respondents (Table 3):

(1) Mussel distributions within the substrate may vary among seasons. Of particular importance, mussels may move upward in the substrate to spawn. Spawning

individuals may extend above the surface of the substrate, and gravid females may occur wholly on top of the substrate. Furthermore, disturbances such as turbulent velocity surges may cause females to abort glochidia.

(2) Mussels may experience greater difficulty reburying at lower water temperatures.

3. Review of questionnaire results.

We summarized the concerns and comments received from the eight individuals who responded to the questionnaire, and drafted general descriptions of vertical distribution with separate estimates for juveniles (< 2 cm in length) and three groups of species. The vertical distribution estimates were based on the responses tabulated in Table 1; Neves and Widlak (Amer. Malacological Bull. 5:1-7, 1987) have observations of juvenile mussels mostly occurring in the top 8 cm of substrate in a VA stream, and so we used this estimate for juvenile depths in gravel bars. Two respondents both identified a group of "shallower" species (both included *Quadrula cylindrica*, *Truncilla truncata*, *T. donaciformis*, *Toxolasma parvus*), which one respondent estimated buried to 5 cm and the second respondent to 15 cm; we assigned a depth distribution of 0 - 10 cm for this group. One respondent identified a group of species likely to occur most abundantly > 8 cm deep, so we assigned depths of 8 - 20 cm for these animals, and assigned depths of 0 - 20 cm for all other species. To estimate morality rates, we used the high estimates by one respondent for large *Megalonaias*, *Elliptio*, and *Amblema*, and used a middle value of 30% (an approximate median of values from two respondents) for all mussels > 2 cm in length. For mussels < 2 cm in length, we averaged estimates from the same two respondents.

The summary of these estimates (Attachment D) was submitted to five USFWS or NBS biologists (Attachment C) with mussel expertise and who either had not seen or had not responded to the initial questionnaire. We asked these reviewers whether the estimates appeared reasonable and usable as a starting point for modeling the vulnerability of mussels to velocity surges capable of disturbing gravel-bar substrate. We received written comments from three reviewers and discussed the issue with NBS reviewers in Gainesville on 20 October 1994.

Three reviewers recommended caution in using the values for depth distribution, stressing again the need for field data. Two reviewers felt the values were reasonable, although one stated his field experience was limited. One reviewer stated that a 10-20 cm substrate loss would likely remove most adults of most species, and that a 0-2 cm loss of substrate would likely remove juveniles younger than 3 yrs of age of most species, causing "in other words, a loss of three years of recruitment effort". Reviewers noted the high variability in mortality rates associated with attempts to relocate mussels, and stressed that mortality likely depends on a variety of factors, including disturbance frequency.

Recommendations

One reviewer summarized his response to the information gathered through this questionnaire process, as follows: "Your data does have potential for creating models. However, the value of such models is debatable. As noted above, navigation has local effects on mussel communities due to degradation of substrate, redeposition of substrate, and sandblasting. Mussel communities, however, continue to survive in deeper channels, or peripheral channels of many navigable systems such as the Ohio River. The potential effects on the mussel community of an increase in running more and bigger barges in such a system is quite predictable: localized declines of mussel communities associated with the navigation channel, and less measurable effects on communities peripheral to the channel."

If such effects of navigation traffic on mussel beds are indeed general and predictable, then at least the gross magnitude of these effects should also be predictable given estimates of likely extent of substrate disturbance, even in the absence of species-specific habitat-use data. All participants in this effort strongly emphasized the lack of available data to estimate mortality rates of dislodged mussels, or to estimate the vertical distribution of mussels except in the most general terms, i.e. most individuals should occur in the top 20 cm or so of gravel bar substrate, and small juveniles may be most prevalent in the top several cm. It does not appear possible at this time to construct habitat suitability models specifically for gravel-bar mussel beds that the scientific/research community would confidently support. However, rather than abandon all attempts to assess potential impacts of future navigation traffic on mussel beds, we recommend using conservative assessments based on likely effects on substrate, until field-data can be collected. One participant in this exercise also stated this recommendation: "If there is a continuing reason to evaluate the effects of navigation traffic on mussels, it might be more appropriate to explore the physical effects of velocity surges on substrate stability and compaction. If the nature of substrate changes as more and larger engines pass by, it would be logical to assume the quality and density of the resident mussel community would also change."

The general estimates of vertical depths obtained in this effort could be used in preliminary models of effects of substrate disturbance on mussel populations, as follows:

(a) For juveniles (post-metamorphosis, to 2-3 yrs of age). The few responses indicate shallow distributions for juveniles, with two respondents estimating nearly all individuals to occur in the top 2 cm of the substrate until age 2 or 3. Therefore, we suggest treating any velocity surge sufficient to displace the sand fraction in the upper 2 cm of a gravel bar as a reduction in habitat suitability to 0 for juveniles; a disturbance to 1 cm could be represented as a reduction in habitat suitability to 0.5 for juveniles. Frequency of disturbance is critical. If juveniles do remain vulnerable to these shallow disturbances for three years, then a disturbance to 2 cm occurring as often as once every three years could result in continual elimination of juveniles - and habitat suitability for juveniles should always be 0 for that location. A disturbance-free period of three years or longer would be required for any juveniles to out-grow this period of vulnerability, and the timing would have to correspond with success in other aspects of reproduction (e.g., spawning, host-fish infection, juvenile settlement). A conservative approach would be, for a given gravel-bar location, to decrease habitat suitability for juveniles as follows, where "disturbance" means a velocity surge sufficiently strong to suspend sand from the gravel-bar substrate to the depth indicated:

(For mussels $\leq$ 3 yrs of age)

| Habitat suitability | Depth of disturbance | Frequency of disturbance |
|---|---|---|
| 1 | <0.1 cm | any frequency |
| 0.75 | 1 cm | < 1 event every three years |
| 0.5 | 1 cm | > 1 event every three years |
| 0.5 | 2 cm | < 1 event every three years |
| 0 | 2 cm | > 1 event every three years |

(b) For mussels older than 3 years. Assume nearly all individuals occur in the upper 15 cm of substrate, and reduce habitat suitability proportionately for velocity surges capable of moving gravel-sized particles to increasing depths, so that habitat suitability drops to 0 for an event that disturbs the upper 15 cm of substrate.

| Habitat suitability | Depth of disturbance |
|---|---|
| 1 | <1 cm |
| 0.7 | 5 cm |
| 0.3 | 10 cm |
| 0 | 15 cm |

Frequency of disturbance, again, probably is critical; however, the experts have provided no bases for estimating how frequently mussels may be able to withstand this type of disturbance. There have been suggestions that mussels are less able to rebury at colder water temperatures. A conservative approach would be to assign to a given gravel-bar location the lowest habitat suitability value observed during a year; with suitability reset to 1 at the beginning of each year, and values averaged across years to estimate longer-term suitability.

These two models would allow preliminary estimates of effects of substrate disturbance on mussel communities. The estimates would be conservative in not allowing for potential refuges for juveniles below 2 cm into the substrate, or for any part of the community deeper than 15 cm into the substrate. These models are not conservative, however, with respect to considering (1) effects of velocity surges on spawning or gravid females, (2) effects on habitat suitability for host fishes, (3) differences among species with respect to vulnerability to substrate disturbances, or (4) effects of zebra mussel biofouling on vulnerability of native mussels to dislodgement. Building realistic habitat assessment models for mussels will require field-collected data.

Expert opinion or knowledge is unlikely to ever produce more than the most general estimates of mussel distribution or vulnerability to current surges created by passing tows. Although Delphi procedures have successfully produced habitat suitability models for other aquatic organisms, participants in this exercise mostly were reluctant to submit even general estimates of species distributions in the substrate. (Experts were even more unwilling to estimate mortality rate following dislodgement.) Our failure to obtain more specific data may in part reflect real variability in mussel behavior. For example, several participants cited the influence of substrate compaction on how deeply mussels bury, and of reproductive status on mussel behavior.

Field work is necessary to quantify vertical distributions of mussels in Ohio River gravel bars. Efforts should also be made to estimate the timing of reproductive activities, i.e., periods when females may be particularly vulnerable to surges in current (and when local habitat suitability for host fishes should be considered), for various species. Juvenile freshwater mussels are, by nearly all accounts, difficult to locate. However, information on the vertical distribution of mussels during their first few years of life will be critical to predicting accurately effects of substrate disturbance on population reproductive success. Conducting field work in the Ohio River, or at specific river locations of concern, would help avoid variability in mussel depth-distributions associated with differences among sites in substrate compaction.

Table 1. Summary of responses to vertical distribution questions; seven individuals responded to one or more questions.

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1. What is the depth into the gravel-bar substrate above which you would expect nearly all (i.e., 99% of the individuals) of the mussel assemblage to occur?

   *6 Responses:* 20 cm (whole animal or posterior of large individuals)
   15 cm
   12 cm
   15 cm (depends on substrate compaction)
   36 cm
   15 cm (depends on substrate compaction and interstitial flow)

2. Would you expect species, or groups of similar species, to differ in their vertical distributions within a gravel-bar?

   *Yes:* 5
   *No:* 2

3. Would you expect differences among size-classes of mussels in their vertical distributions within a gravel-bar?

   *Yes:* 7
   *No:* 0

*Three respondents estimated vertical profiles for one or more distinct groups of mussels:*

a. (First respondent): Probably all juveniles, 0 - 2 cm in length, occur at depths of 0 to 8 cm. "This is wild, far out speculation for individual species or groups of species".

b. (Second respondent):

| Depth into the substrate | Juveniles, all spp. 0 - 1 cm long | "Spp Group A"[1] 1- 5 cm long | All other spp. 6 - 20 cm long |
|---|---|---|---|
| 0 to 1 cm | 75% | | |
| >1 to 2 cm | 25% | | |
| >2 to 3 cm | | 25% | |
| >3 to 4 cm | | 50% | |
| >4 to 5 cm | | 25% | |
| >10 to 20 cm | | | 10% in each 10 cm increment, down to 20 cm deep |

[1] *Tritigonia, Q. cylindrica, T. truncata, T. donaciformis, Toxolasma*

(Table 1, cont.)

c. (Third respondent):
Depth into the
substrate

All size classes of *Q. cylindrica, T. truncata, T. donaciformis, Toxolasma parvus, Leptodea fragilis:*

| | |
|---|---|
| 0 to 8 cm | 30% |
| >8 to 15 cm | 50% |
| > 15 cm | 20% |

All size classes of *Lasmigona complanata, Q. metanerva, Q. nodulata, Obliquaria reflexa, Potamilus alatus, Lampsilis teres* f. *teres, L. teres* f. *anodontoides, L. ovata*:

| | |
|---|---|
| 0 to 8 cm | 10% |
| > 8 to 25 cm | 70% |
| > 25 to 36 cm | 20% |

*Megalonaias, Tritigonia, Q. quadrula, Q. p. pustulosa, Amblema plicata, Fusconaia ebena, F. flava, Pleurobema cordatum, Cyclonaias tuberculata, Plethobasus cooperianus, P. cyphus, Elliptio c. crassidens, Ellipsaria lineolata, Obovaria olivaria, Ligumia recta*:

| | |
|---|---|
| 0 to 20 cm | 70% |
| >20 to 36 cm | 30% |

Table 2. Summary of responses to mortality rate questions; seven individuals responded.

1. Would you expect differences among species in the probability of mortality for an individual that was dislodged from its position in the substrate and then re-deposited?

   *Yes:* 7
   *No:* 0

2. Would you expect differences among different mussel size-classes in the probability of mortality for an individual that was dislodged from its position in the substrate and then redeposited?

   *Yes:* 7
   *No:* 0

*Two respondents estimated mortality rates for species and size-classes, as follows:*

a. (1st respondent),

| | |
|---|---|
| All species, 0-2 cm | 80% |
| *Megalonaias*, 12 cm+ | 90% |
| *E. crassidens*, 10 cm+ | 90% |
| *Amblema*, 10 cm+ | 70% |
| *Leptodea*, 2 cm+ | 30% |
| *Potamilus*, 2 cm+ | 40% |

b. (2nd respondent), *T. truncilla, T. donaciformis, Toxolasma parvus, Q. nodulata*:

| | |
|---|---|
| 0 - 3 cm | 50% |
| > 3 cm | 20% |

All other species:

| | |
|---|---|
| 0 - 4 cm | 50% |
| > 4 - 8 cm | 30% |
| > 8 cm | 20% |

Table 3. Summary of responses to questions concerning "Other Considerations"; seven individuals responded.

1. Should separate vertical profiles of mussel distributions in the substrate be developed for different seasons?

   *Yes:* 5 (one estimate: add 5 cm to all profiles during winter; 3 respondents refer to increased vulnerability of spawning or gravid females)
   *No:* 1
   *Maybe:* 1 (not high priority)

2. Should mortality rates for mussels dislodged from the substrate be estimated separately for different seasons?

   *Yes:* 5 (one estimate: increase all mortality to 80% during winter/spring; 3 other respondents cite possible effects of lower water temperate on ability to re-bury)
   *No:* 2

3. Would you expect large differences among mussel species that differ in shape or shell-characteristics in their susceptibility to dislodgement by velocity surges?

   *Yes:* 6
   *No:* 0

4. Should species differences in vulnerability to velocity surges be incorporated in assessments by NAVPAT (as opposed to assuming that all mussels occurring to a given depth in the substrate are dislodged by a velocity surge that moves the gravel substrate to that depth)?

   *Yes:* 1
   *Yes, but no data presently available to do so:* 1
   *No:* 1 ( *prefer to assume that all would be affected to some depth*)

Additional Comments:

*"A large, heavy shell may not be moved even if gravel is dislodged. However the disturbance may still impact the mussel".*

*"I would expect dislodgement and reburrowing differences to be controlled by individual size, weight, shell roughness, and (last) behavior".*